Temperature Dependent Mobility Characterization and Modeling of Strained Si *n*-MOSFETs

Personnel

G. (Maggie) Xia (J. L. Hoyt)

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SRC and IBM Corp.

An attractive method to enhance MOSFET performance is to alter the band-structure of silicon to improve the carrier transport properties. This can be achieved by inducing biaxial tensile strain in the silicon channel. For example, epitaxial growth of 10 nm-thick layers of silicon on relaxed SiGe (20% Ge) will provide sufficient strain in the silicon. Recent results on the application of these concepts to silicon MOSFETs indicate significant strain-induced performance enhancements at a given channel length, in the deep sub-micron regime. Under-standing the mobility enhancement mechanism is important for determining the ultimate performance limits of these devices.

In this project, we begin by studying issues related to the electron mobility in strained Si MOSFETs. One method of understanding the mechanism of mobility enhancement is to study the vertical effective field dependence of the mobility as a function of temperature. For high vertical fields (>1 MV/cm), it is anticipated that surface roughness scattering will dominate transport. The impact of strain on surface roughness scattering is not understood at this time. Lowering the measurement temperature reduces the phonon component of scattering, and thus enables us to observe the remaining mobility terms, which include Coulomb and surface roughness scattering, in strained and unstrained Si devices.

Strained Si n-MOSFETs (20% Ge) and unstrained Si control wafers with similar doping profiles were fabricated by K. Rim (Ph.D. thesis, Stanford). Measurements and modeling of the mobility behavior as a function of temperature are shown in Figure 10. The surface roughness mobility term dominates the mobility at low temperatures (e.g. 30K) and at room temperature at high vertical effective fields. The surface roughness mobility term appears to be enhanced by almost a factor of three, at a vertical effective field of 1.4 MV/cm. The results suggest that surface-specific mechanisms may be involved in the strain-induced electron mobility enhancement.

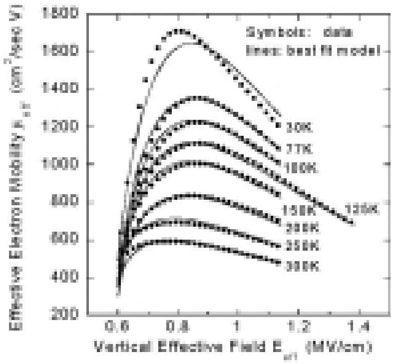

Fig. 10: Comparison of measured strained Si n-MOSFET mobility with the model in this work. Symbols and solid lines represent the experimental data and the best fit model, respectively.

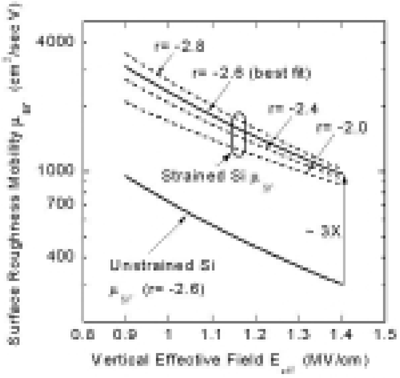

Fig. 11: Extracted surface roughness limited mobility for strained and unstrained Si devices. For strained Si, the fit to the data is down with various values of the parameter, r, which is the power dependence of this mobility term on the vertical effective field (r = 2.6 ± 0.2 gives the best fit to the data).